UNITED STATES
COAST AND GEODETIC SURVEY

T. C. MENDENHALL
SUPERINTENDENT

GEOGRAPHICAL EXPLORATIONS

REPORT OF AN EXPEDITION
TO
MUIR GLACIER
ALASKA

By HARRY FIELDING REID
Professor of Physics, Case School of Applied Science
Cleveland, Ohio

APPENDIX No. 14—REPORT FOR 1891

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REPORT OF AN EXPEDITION TO MUIR GLACIER, ALASKA, WITH DETERMINATIONS OF LATITUDE AND THE MAGNETIC ELEMENTS AT CAMP MUIR, GLACIER BAY.

By HARRY FIELDING REID,
Professor of Physics at the Case School of Applied Science, Cleveland, Ohio.

Submitted for publication December 10, 1891.

INTRODUCTION.

In the spring of 1890 a party was formed, consisting of Messrs. H. P. Cushing, H. McBride, R. L. Casement, J. F. Morse, C. A. Adams, and the writer, for the purpose of exploring and studying Muir Glacier, Alaska. All my companions rendered most efficient aid. Mr. Cushing took entire charge of the geological and meteorological observations. Messrs. Adams and Morse did most of the trigonometric work, while the writer did the plane table work, made the magnetic and latitude observations, and had general charge of the expedition. We established our camp, which we named Camp Muir, near the end of the glacier, on July 1, 1890, and remained there until the middle of September, mapping and studying the region.

Many of the necessary instruments were lent us by the U. S. Coast and Geodetic Survey. A list of them will be given at the end of this report.

General Geography.—The southeastern extremity of Alaska consists almost entirely of an archipelago of islands, which occupies a space nearly 350 miles long and 100 miles wide. These islands, large and small, are closely packed together, and the waterways between them are deep and narrow, and often form long strait canals. The islands are mountainous and precipitous, affording few landing places. Their slopes are densely wooded, mostly with spruce. The rough surveys of Vancouver, a hundred years ago, as revised later by Tebenkof and others, were, until 1867, largely relied upon as supplying the most accurate informa-

tion of parts of the coast. Since that year the explorations and surveys made by the U. S. Coast and Geodetic Survey, under the direction of Assistant Davidson, Acting Assistant Dall, and during the period from 1881 to the present time by officers of the Navy attached to the Coast Survey Service, have resulted in the publication of charts and Coast Pilots making known the more important channels and waterways with ample accuracy for all purposes of navigation. Southeast of the Alaskan boundary the islands become larger and the waterways wider. Cross Sound and Icy Strait form the northwestern boundary of the archipelago. From them two deep inlets, Linn Canal and Glacier Bay, stretch to the north and northwest, forming, with the Pacific Ocean, two peninsulas.

Tho great Fairweather group of mountains occupies the western part of the peninsula between Glacier Bay and the Pacific. The eastern part is occupied by another and much lower range, whose peaks rise about 1 800 metres above the sea. Their northeastern slopes are gradual, and are covered with large glaciers, some of which reach tidewater and discharge icebergs into Glacier Bay. Between these two ranges there seems to be a deep valley, which drains the eastern slopes of the Fairweather group. This is probably filled by a long narrow glacier discharging into Taylor or Dundas Bay.

Little was known of the peninsula between Glacier Bay and Lynn Canal before our expedition mapped its northern part, except that it is entirely made up of glacier-bearing mountains, whose peaks are from 1 800 to 2 400 metres high.

Northwest of Cross Sound the character of the coast changes abruptly; the coast line becomes continuous without outlying islands and broken by few inlets. Mountains of great height rise immediately from the water's edge. We can therefore topographically divide the southeast coast of Alaska into two regions; the line between them passes along Cross Sound, then follows the valley just northeast of the Fairweather range for 60 or 80 kilometres, beyond which point we know nothing whatever about it. This topographical difference seems to be accompanied by a geological difference. Mr. Russell has shown that the St. Elias Alps are of tertiary origin, and probably the Fairweather group belongs to the same range, though I believe it has not been at all explored. If this is true, the Fairweather Mountains are of tertiary origin, while the mountains about Muir Glacier, and probably the rest of the same topographical region to the southeast, belong to paleozoic and archean time. (*See* Nat. Geog. Magaz., Vol. IV, Supplements I and II to "Studies of Muir Glacier".)

Another difference is quite marked. Mr. Russell has found raised beaches about Yakutat Bay, indicating that the land there has risen, whereas the submerged trees in Muir Inlet show that this region is sinking. These striking facts seem to show that the valley between the Fairweather Mountains and Glacier Bay follows the line of an

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immense geological fault, which brings tertiary and paleozoic rocks into close juxtaposition. It is most unfortunate that we have no observations on the Fairweather Mountains that will enable us to confirm or correct this interesting indication.

Glacier Bay and Muir Inlet.—Glacier Bay itself has not been surveyed; its delineation in the Coast Survey charts is correct only in its general outline. It lies northwest and southeast and is about 65 kilometres long by 15 kilometres wide. There are a great many islands in the bay. The Beardslee Islands, which fill the eastern side for a distance of about 30 kilometres from its mouth, are made up, at any rate, in part, of modified glacial till, and are generally thickly wooded, as are also the shores in the lower part of the bay. The channels betweeen these islands are narrow, and often give one the impression of waterways cut through the land. The islands in the upper part of the bay are quite different; they are of solid rock, and are scored, polished, and rounded by glacial action; they occur singly, are usually elongated, and have the long axis parallel to the nearest shore. They, like the main land, descend abruptly into the water, and only at long intervals can even a small beach be found. In this part there are no trees. Several glaciers force their way down to the water's level and discharge bergs into the bay; most of them end in a narrow inlet two or three miles back from the bay proper. Muir Glacier is of this type; its inlet, which runs about north and south, has its southwestern terminus on Glacier Bay about 8 kilometres from the end of the glacier; the eastern shoreline rounds gradually into the bay without any well-marked headland. The inlet gradually narrows as we approach the glacier, being about 2·5 kilometres wide at its upper end. On each side are deposits of roughly stratified sands and gravels, covered with a thin layer of moraine debris. On the west side, these deposits form a comparatively level plateau from 45 to 60 metres high, which extends about 6·5 kilometres south of the present ending of the glacier, and is about 1·6 kilometres wide. Its surface bears a number of shallow lakes; and here and there deep ravines mark the position of former water courses. The western subglacial stream has cut a gorge through this plateau, and exposed the buried forest described by Prof. Wright.* For three-quarters of its length the plateau ends on the water side in precipitous bluffs, below which there is a narrow beach, only covered by the highest tides. On the east side the bluffs only extend for a kilometre or so; the upper surface of the deposit is not a plateau, but slopes gradually down to the bed of the glacial stream at the foot of the mountains. This stream empties into the inlet just below where the bluffs end. South of the stream the deposits slope gradually up from the beach to a height of about 120 metres against the mountain side.

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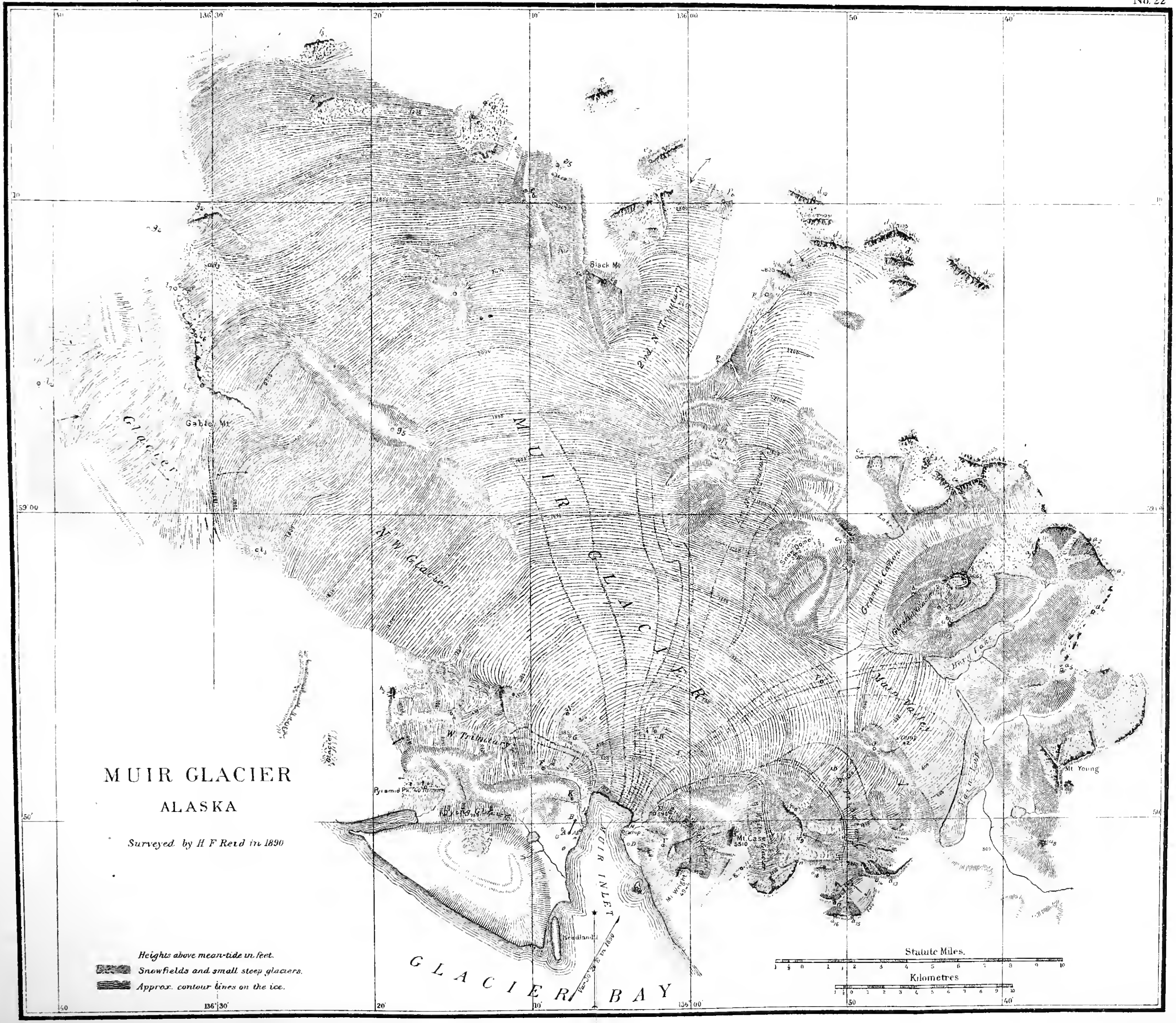
*Ice Age in North America, ch. III.

The inlet is quite deep. Prof. Wright reports a sounding by Capt. Hunter of 86 fathoms about 1 200 metres south of the present position of the ice-front. Capt. Carroll last summer (1890) found within 100 metres of the ice-front a depth of 120 fathoms. This does not necessarily indicate that the inlet increases in depth as we approach the immediate neighborhood of the ice, for the earlier sounding may not have been taken in the deepest part of the channel.

Muir Glacier.—Muir Glacier (see illustration No. 22) occupies a depression in the mountains about 60 kilometres long and from 10 to 15 wide. It is fed by a great number of tributaries, of which the First Northern, the Second Northern, and the Northwestern are by far the largest. These again are made up of many smaller glaciers. The general slope of the surface is about a degree and a quarter. This is based on a barometrical reading made between Tree Mountain and Granite Cañon. The appearance of the glacier to the northwest indicates that the slope there is about the same. The total area drained by this system is about 2 250 square kilometres, the actual surface of the ice being about 1 000 square kilometres. The area draining into Muir Inlet is about 2 000 square kilometres. Most of the precipitation which falls on this area flows off as water in the subglacial streams; the rest, compressed into ice, is forced through the narrow gateway about 4 kilometres wide into the inlet, where the glacier terminates in a vertical wall of ice, varying from 40 to 65 metres above the water's surface, from which large masses are continually separating to become icebergs. As already said, the depth of the water is in places 120 fathoms or 220 metres, and as this is not enough to float a mass of ice which rises as high above the water as Muir Glacier does, the ice must reach to the very bottom, and must attain a thickness of 275 metres. The actual length of the ice-front facing the water is 2 800 metres. On each side the glacier sends forward a wing, which rises in the shape of a wedge over the stratified sands and gravels of the shore. The upper surfaces of the wings, like the ice-front, are about 60 metres above the water level. This applies only to the parts of the wings overlooking the inlet; the parts nearer the side mountains are 15 to 30 metres lower, and here the ice ends like an ordinary alpine glacier. The wings are fringed by treacherous quicksands, which support large stones and look firm enough, but the tourist who steps upon them carelessly will quickly sink in over his ankles. These quicksands are composed of fine glacial mud, thoroughly soaked with water from the melting ice.

The ice-front has a wonderful coloring. Places from which ice has recently broken off are deep blue, sometimes almost black. This color lightens under exposure to the air and sun, and in a few days becomes pure white. All stages are represented in the ice-front, which therefore shows all shades of blue in striking variety.


MUIR GLACIER
ALASKA
Surveyed by H F Reid in 1890
Heights above mean-tide in feet.
Snowfields and small steep glaciers.
Approx. contour lines on the ice.
MUIR GLACIER
N.W. Glacier
Glacier
Gable Mt.
Black Mt.
W. Tributary
Pyramid Pk.
Snow Dome
Mt. Case
5510
Mt. Young
Headland
MUIR INLET
GLACIER BAY
Statute Miles.
Kilometres
136°30'
136°00'
59°00'

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Tributaries.—Beginning at the right (see the illustration), we find three tributaries coming in from the southeast. The Dirt Glacier sweeps around in a great curve from behind Mount Wright; its lower part is completely covered with débris for fully 2·5 kilometres from its mouth; above this the glacier is particularly clean. The White Glacier, which joins the Muir just beyond Mount Case, is remarkably beautiful. Arising in a circle of snowy mountains, it flows down a deep and narrow valley at an angle of about 10°, its very white surface marked by the wonderfully symmetrical parallel curves of three or four dark moraines. It is about 6·5 kilometres long and 0·8 wide. A little farther is the Southeastern Tributary, fed by a number of smaller glaciers. This glacier is not hemmed in by mountains, but crosses a divide to the east of a_{15}, over which the ice flows into some valley on the other side. This divide has an altitude of 600 or 750 metres. About 15 kilometres southeast of our camp a large glacial stream discharges into Glacier Bay. It must drain the southern side of the mountains which bound these three tributaries. A little farther to the east is Main Valley, which, though it probably once contained a tributary, is now an outlet of Muir Glacier. The ice flows down this valley in a stream 3 miles wide, but apparently with a very slow motion. A few miles down the valley the ice ends in a high wall facing Main Lake, into which it occasionally discharges a berg. The stream draining this lake flows through a broad flat valley of sands and gravels to the southeast, and finally empties into Lynn Canal. The three valleys entering the eastern side of Main Valley also have flat, gravel-covered floors, through which rush the streams from the snow fields and small glaciers at their heads. Two of these valleys are beyond the present termination of the glacier. Formerly the ice must have extended across their mouths, hemming them in and converting them into lake beds. The upper valley is now in just this condition. The lake which occupies it has been called Berg Lake on account of the great number of icebergs in it last summer (1890). Just to the north of the entrance to Main Valley lies the Girdled Glacier, so called on account of the moraine which completely surrounds it; it can be seen from the end of Muir Glacier, but is so fore-shortened that one would not suspect that the visible portion is 5·5 kilometres long. To the west and separated from the Girdled Glacier only by a narrow ridge is Granite Cañon, a deep gorge with precipitous sides running about 13 kilometres into the heart of the mountains.* The ice slopes downward into the cañon, whose drainage, however, must be back under the ice; for although I was unable to see every point of the ridge which closes in the back of this valley, I could see sufficient of it from different points of observation to convince me that no part of it was less than 300 metres above

* This was named from the crystalline nature of the rock, which, however, is not a true granite. (See paragraphs under heading *Geology*.)

the floor of the valley. This curious condition seems to be due to the fact that this valley once contained a tributary glacier, which on account of the present smaller supply of ice, and the reflection of the heat from the northern side of the cañon, has melted down more rapidly than the surface of the main glacier; so that now, although this I could not see, the glaciers draining into this valley are probably entirely separated from the ice entering at its mouth. The tributaries so far mentioned supply none of the ice which forms ice front in Muir Inlet; all the ice coming from them that does reach the end of the glacier is compressed into about 750 metres between the ice front and the mountain to the east. If a line were drawn from station H to the eastern side of the first Northern Tributary, and a second line to the northwest at right-angles to the first, the sources of all the ice which reaches the ice front would lie in the quadrant between them.

The first and second Northern Tributaries, and the main glacier present no striking peculiarities. These are immense streams of ice fed by innumerable smaller glaciers; the mountains which rise between them and through them are deeply laden with snow, and toward the northwest seem to raise only their summits through the icy sea. The extremities of these branches could not be clearly determined, although they all seem to connect by low divides with valleys beyond. The Northwestern Tributary heads in two beautiful white conical-looking mountains, which we have called the Snow Cones. A part of its ice flows over the divide between l_3 and l_5 and joins a large glacier which is probably identical with the one which enters the head of Glacier Bay. The Western Tributary supplies no ice to the ice front; moreover, its snow fields are too small and too low to supply ice for a glacier of its width, and it is evidently melting away. At its western extremity it crosses over a divide and flows into a valley beyond.

The mountains immediately surrounding Muir Glacier are not high, the highest peaks being between 1 800 and 2 400 metres. The mountains which first attract the attention of the visitor are Mount Wright,* Mount Case,† and Pyramid Peak; the first two, by their jagged crests, seamed by snow couloirs; the last by its symmetrical form; all three by their proximity. The more distant mountains seem to lack somewhat in individuality; this is largely due to their distance, for they are from 25 to 50 kilometres away. All is bare and bleak, and the scenery is entirely lacking in picturesqueness. If we go out on the ice as far as H the three bold peaks of Mount Young show themselves over Tree Mountain; and the beautiful Snow Cones at the head of the Northwestern Tributary can be seen.

Drainage.—The principal drainage of the glacier is into Muir Inlet. On each side of the inlet a large stream issues from the end of the ice

* Named after Prof. Wright, who spent some time studying Muir Glacier in 1888. He has described it in his Ice Age in North America.

† After the Case School of Applied Science, Cleveland, Ohio.

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at a number of points, and after a rapid course of between 1·5 and 2·5 kilometres empties into the inlet, forming quite a large delta. These streams were about 10 metres wide and half a metre deep. Their course is so swift that they roll down stones as large as one's fist; but the principal material that they carry off is in the form of fine mud. We used this water largely in our camp, and found that although most of the mud would precipitate when allowed to stand for a few hours, still the water remained quite turbid even after three or four days. The muddy character of the water in the inlet a little west of the middle of the ice front shows that another stream must discharge in that region, either under or through the ice. A small part of the drainage of the glacier passes down Main Valley, but this does not amount to very much. I think the principal sources of the stream in this valley are from the snow fields and smaller glaciers on its sides.

Geology.—The geological observations were undertaken by Mr. Cushing. Some rocks collected near the glacier were submitted for microscopical examination to Dr. George H. Williams, of the Johns Hopkins University. The following is extracted from their reports.* The rock bordering the glacier on the south and southeast is slate. It has a very variable, but in general, high dip to the southwest, and is much faulted. On the east side of Muir Inlet this is overlaid conformably by limestone, the junction reaching tide water, about 13 kilometres southeast of the glacier. The southwestern shore of Glacier Bay and the islands near it are composed of this rock. In one of these islands Mr. Cushing found fossils which make it probable that the limestone and underlying slate are of paleozoic age.

The western part of the glacier's basin consists of quartz diorite, light gray in color. The line of junction with the slates, beginning at the small glacier on the northern shoulder of Pyramid Peak, runs easterly, passes between the F and K ridges, and then between H and I. It then turns to the northwest, passing between g_5 and f_2. The northern mountains are diorite, bordered on the south by a narrow band of slate. The eruptive rocks (the diorites and quartz diorites) are full of dikes running in all directions. The eruptions occurred at two or more periods. Some of these rocks are very old, and closely resemble archean terranes occurring in the Cordilleras further south. Although the difficulties of travel prevented Mr. Cushing from examining the region very thoroughly, he thinks we have to do here with a tilted block dipping towards the southwest, but much distorted by minor folds and by faults.

Changes going on.—Many indications show that Muir Glacier is becoming smaller, and considerable changes may be expected before many years. Main Lake and Berg Lake are now separated by a very

*These reports are given in full in "Studies of Muir Glacier," Nat. Geog. Mag., Vol. IV.

short distance, and it will not be long before they unite. This will result in the draining of Berg Lake, which event will probably be marked by a flood. The melting of the ice in Main Valley must be rapid, for the great extent of its termination there presents a large surface for melting. When this termination has receded 4 or 5 kilometres, and the surface of the ice has sunk 60 to 100 metres, the ice from the first northern and from the southeastern tributaries will probably be in part deflected into Main Valley.

The small lake which occupies a lateral valley opening into Granite Cañon will probably extend as the ice diminishes, and perhaps occupy a large part of the cañon itself.

Prof. Wright has kindly sent me some photographs which he took of the glacier in 1886. By comparing these with our photographs we can readily fix on our map, within 100 metres, the position of the ice front at the time of Prof. Wright's visit. This shows that in the four years from 1886 to 1890, the western end of the ice front has receded 1 100 metres and the eastern end 900 metres. The center has also receded about 1 100 metres, so that the average recession of the ice front is about 1 000 metres in four years. Prof. Muir writes me that the notes of his first visit to the glacier in 1879 show that the ice then extended almost to our station D. The rate of retreat deduced from this accords fairly well with that given above. The ice front, therefore, must have extended as far as island C twenty years ago. Below C, I think the retreat was more rapid, for there the glacier presented a much wider front to the water, from which a correspondingly larger quantity of ice must have broken off. And this could hardly have been entirely compensated for by a greater velocity of flow, on account of the many obstructions in the neighborhood of the present position of the ice front. It does not seem at all incredible that the ice from the various glaciers of Glacier Bay may have united to fill a large part of the bay a hundred years ago. Prof. Wright's interpretation of Vancouver's description seems perfectly in accord with what our observations would lead us to conclude.

The retreat is probably not regular, but is faster some years than others; and even varies considerably at different parts of the same season. For two or three weeks in August (1890) there was scarcely any fall of ice; in the two weeks following the fall was so rapid that a great bay, fully a quarter of a mile deep, was made in the eastern part of the ice front, which was, before this, only slightly concave. I have collected on the map the positions of the ice front at several periods; this shows the retreat at a glance, much better than it can be described in words. The changes in the shape of the front will also be evident.

The present rate of recession of the ice front in Muir Inlet, a kilometre in four years, will probably be exceeded in the near future, for it has reached a point where the conditions change. The deposits which support the wings are almost at the water's level at the ice

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front, and slope down at an angle of 6° or 7°; a little further back they will be below the water's level and the ice front will be broader, resulting in an increased amount of loss by breakage, and hence a more rapid retreat. Ten or fifteen years will probably see the Dirt Glacier on the east and the Western Tributary on the west, entirely separate from the main ice stream. The middle part of the valley which connects Muir Inlet with the upper part of Glacier Bay is now occupied by a small glacier without feeders, evidently the remains of a much larger body of ice. It probably derived its supply principally from the main body of ice which formerly filled the bay. This glacier, which we called the Dying Glacier, is rapidly melting away; in fifteen or twenty years I think its bed will be empty. The maps I have made will enable us to determine with considerable accuracy the amount of these changes in the future. I should, however, say that although the northern end of Main Lake is in its right place, the southern end is only approximately determined. The ends of the Dying Glacier are also only approximate.

THE SURVEY.

I.—BY TRANSIT.

The west side of the inlet was the best place for measuring our base line, as it offered a pretty long stretch of fairly level ground. The base line was measured on July 5, with a 30-metre steel tape (No. 23 U. S. Coast and Geodetic Survey).

Wooden stakes were driven into the ground, and into the top of each was driven a tack; the measures were all made from the north edges of the tacks. The tape was stretched by a spring until the tension was 16 pounds. Where the ground sloped, the tape was held as nearly level as possible, and plumb bobs were used to project the tape upon the edge of the tack. The base was measured twice, first from B to A, and then from A to B. The two values obtained were 962·301 and 962·330 metres. This close agreement shows that the measures were carefully made; and the average adopted, 962·32 metres, is probably not in error by 5 centimetres. The temperature of the air was 12·5° C., and would cause but a slight correction if the tape, as usually made, were correct at ordinary temperatures. No temperature correction was introduced. White flags were planted at the ends of the base line and the stations called B (north end) and A (south end). The stations A and B were then determined trigonometrically. Angles were taken from these stations and from D, Camp, E, and K. The transits used were Casella 120 and 3123, having $2\frac{3}{4}$-inch horizontal and vertical circles reading to minutes by two verniers, and telescopes magnifying $5\frac{1}{2}$ times. The angles were measured several times; the sum of the three angles of the various triangles differed on an average about 2′ from 180°. The excess or defect was divided between the three angles,

but no attempt was made to make the sum of the angles at a particular station equal to 360°. The points L, M, b_4, c_2, were also determined trigonometrically, but the transit was not set up at those points. The following are some of the distances thus determined (A—B is the base line measured):

	Metres.		Metres.
A—B	962·32	D—M	1075·6
E—D	2492·2	E—M	1973·2
D Camp	819·26	M—L	2444·7
E Camp	2201·2	E—*b*4	23713
D—L	3091·0	E—*c*2	28865
E—L	4110·2		

The distance D—E was determined through the four triangles B, D, E; K, D, E; Camp, D, E; and A—B, D, E; the other two sides of each of these triangles having been already determined. The average gives 2492·2 as in the table, which is probably true to the fourth figure. At E and at D cairns of stones were made surrounding the flag. These cairns were about four feet high, and were made of the largest stones that we could move, so piled up as to hold the flags firmly in their midst. I think they will remain if unmolested five or ten years, and will serve to connect our map with any future surveys that may be made in this region. If these cairns should not last I think the two peaks, Mount Wright and *c*4, would make the best points of connection. The former on the east side of Muir Inlet can not be mistaken; the latter is a sharp peak with symmetrical shoulders, and when seen from the end of the glacier is slightly to the west of the entrance of Granite Cañon. It is the highest peak in its neighborhood.

The meridian line was determined near our camp in connection with observations for magnetic declination, but it was not determined at any of our trigonometric stations, and therefore we must determine the orientation of our map graphically. This gives for the direction of the line E—D, N. 41° 43′ E. (astron). The error is probably not more than 5′.

Altitudes were determined trigonometrically with respect to Camp Muir, and 8 metres (the estimated height of the latter above mean tide) added. The following are some of these altitudes:

	Metres.		Metres.
Camp Muir,	8	Mount Case,	1 679
E,	271	Wright,	1 507
D,	32·5	*b*4,	1 678
A,	53	*c*2,	1 995
B,	59	*d*2,	2 175
Pyramid Peak,	1 240	*d*4,	1 473

We expected to determine many altitudes by simultaneous observations of the barometer at camp (mercurial barometer 1738, Coast and Geodetic Survey) and of the aneroids at other points. But the latter instruments worked so unsatisfactorily that few of our barometrical altitudes were reliable. Only the reliable ones have been entered on the map.

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II.—BY PLANE TABLE.

The instrument used was Plane Table No. 81 of the U. S. Coast and Geodetic Survey. The table itself was 39 by 49 centimetres. The top, alidade, and tripod complete weighed about 40 pounds, and was very clumsy to carry.

The scale of the map was 1–99300. This was changed to 1–100000 for the final map. I have carefully abstained from filling in uncertain portions of the map conjecturally; I have, however, in some places added with dotted lines the ridges or peaks whose positions were roughly determined, also the boundaries of some small tributary glaciers, when the positions of the surrounding ridges made it probable that no serious error could be made. Contour lines of 200 feet were added on the glacier to show the general shape of its surface, but they pretend to no accuracy.

The survey was begun at E and H. The point H, though not determined trigonometrically, had its position fixed as soon as some trigonometric stations were plotted in. The plane table was also set up at Camp, D, L, M, O, P, R, N, S, T, and V; the positions of all these stations except the first four being determined by the three-point method, by aid of mountain peaks, which had already been plotted in. The points determined by plane table or trigonometrically are marked thus: ⊙, on the map. I do not think any of these points are out of their true position by 1% of their distance from E. At each of the stations V, O, P, R, N, and T, a number of photographs were taken in different directions. These have been very useful in working up details of topography, and in some instances have served to fix with considerable accuracy the position of certain peaks and thus the direction of some ridges. I have also made a map* of the northern part of the Muir Inlet on a scale of 1–20000. This map shows pretty well the general topography of this region, and also the position of the ice-front at various dates. It also shows where we planted our flags for measuring the motion of the ice. This work was carried out with great care. The greatest velocity we found was 2.2 metres a day for Flag 6[1]. The side flags showed scarcely any motion.

Geographical position.—The latitude of our camp was determined by the following observations on the meridian altitude of the sun, made with the Casella $2\frac{3}{4}$-inch transit No. 120:

Date.	Station.	Latitude of station.	Latitude of Camp Muir.
1890.		° ′	° ′
July 13	Camp Muir,	58 49·75	58 49·75
16	E,	58 50·25	58 49·75
17	K,	58 50·50	58 49·50
Sept. 8	Camp Muir,	58 50	58 50

* See Nat. Geographic Magazine, Vol. IV, Plate 15.

This gives an average of 58° 49′.7 for Camp Muir. Our instruments read to minutes, so that this average can not be relied on closer than a half minute, though I do not think the error is greater than this. This would make the latitude of E 58° 50′.5.

No satisfactory determination of longitude was made. When we first went into camp the chronometer was unfortunately allowed to run down; and when we left, it stopped without any apparent reason. An attempt was made to determine longitude by comparing our chronometer with those of the steamers of the Pacific Coast Steamship Company, which brought tourists every week to see the glacier; but these chronometers differed so much among themselves that no reliance could be put on the result.

Mr. Junken, of the Coast Survey, by reference to the best map of the region, which is somewhat conjectural, has given me as the longitude of our camp 136° 8′ west of Greenwich, which he thinks is not in error more than 5′. I have adopted 136° 5′ west.

The eastern limit of the region surveyed must lie between 12 and 20 kilometres from the shore of Lynn Canal, and probably the mountains on the east of our map are visible from Sullivan Island. Davidson Glacier must have tributaries in the mountains which close up Granite Cañon. Whether or not one of its tributaries connects by a comparatively low divide with the First Northern Tributary of Muir I can not say; but it does not seem impossible. If there is any such connection between these two glaciers, the point indicated is where it will undoubtedly be found.

Magnetic observations.—These were made with the Bache Fund Magnetometer and Dip Circle No. 12 (of about 24 centimetres diameter), both belonging to the Coast and Geodetic Survey. The magnetometer was not adapted for determining deflections, but only for declinations and oscillations. For the latter a mean time chronometer (No. 1285, Coast and Geodetic Survey), was used. The moment of inertia was determined in the field. For this purpose a special stirrup was made. The upper bar of the stirrup was cylindrical, 2 millimetres in diameter, and carried two small brass cylinders, which could slide on it so as to press against stops near the center of the bar (cylinders "in"), or against stops at the ends of the bar (cylinders "out"). The moment of inertia of the system could thus be altered by a definite amount (the increase was about four-fifths of the moment of inertia with cylinders "in") without changing the mass. The masses and distances between the centers of mass of the cylinders, "in" and "out," were determined in the laboratory before starting on the expedition.

The variation of magnetic moment with temperature was determined. Two series of observations gave, respectively, for the coefficient of variation for 1° centigrade, ·00073 and ·00077. The mean was adopted. The magnetic moment of the magnet was determined some time after our return; and I do not think the values of the horizontal and total forces can be relied on more closely than 1 or 2 per cent.

Report of an Expedition to Muir Glacier, Alaska, etc.—Continued.

Quantities given in this report are in Coast and Geodetic Survey units (C. G. S). In the observations for declination, the astronomical meridian was determined by afternoon observations on the sun.

Special tents were erected for the magnetic instruments at Camp Muir. The magnetometer was 80 and the dip circle 60 metres from our tents. During the observation with the former the latter was about 100 metres distant.

Magnetic observations at Camp Muir, Glacier Bay, Alaska.

Date.	Declination.*	Daily approximate range.	Dip.	Horizontal intensity.	Total intensity.
1890.	° ′	′	° ′		
Aug. 22				·150	
23			75 49·8		
Sept. 5			75 51·7		
8	— 30 27·8	6·9			
9	— 30 26·1	8·4			
10	— 30 24·1	5·4			
Mean,	— 30 26	6·9	75 50·8	0·150	0·614

*The negative sign means easterly declination. The observations were made by the writer.

Meteorological.—Regular observations were made under the direction of Mr. Cushing, and a complete record sent to the U. S. Signal Service. The barometer used was No. 1738 of the Coast and Geodetic Survey. The maximum, minimum, wet, and dry bulb thermometers were lent me by Prof. Whitman, of Adelbert College. The rain gauge was lent by the Signal Service.

A short summary of these observations is appended.*

1890.	Temperature. (Fahrenheit scale.)			Barometer. (Inches.)			Rainfall.	Mean humidity.
	Mean.	Max.	Min.	Mean.	Max.	Min.		
	°	°	°					
July. .	45·2	63·1	35·4	30·089	30·335	29·565	3·06	82·2
Aug.	45·1	63·9	27·2	30·123	30·418	29·787	4·88	83

LIST OF INSTRUMENTS LENT BY THE U. S. COAST AND GEODETIC SURVEY.

Two Casella Theodolites (Nos. 120 and 3123).
Two Telemeters (No. 81).
One 20-metre Steel Tape (No. 23).
One Plane Table (No. 81).

* For an account of other observations made on this expedition see Studies of Muir Glacier in the Nat. Geog. Mag., Vol. IV.

One Bache Fund Magnetometer.
One Mean Time Chronometer (No. 1285).
One Dip Circle (No. 12).
One Artificial Horizon (No. 30).
One Mercurial Barometer (No. 1738).
One Prismatic Compass (No. 108).
Two Draw Telescopes (Nos. 114 and 116).
One Clinometer (No. 3).
Two Negretti & Zambra Deep-Sea Thermometers (Nos. 66727 and 57080).
Two Casella Aneroid Barometers (Nos. 1098 and 2738).

The telemeters, artificial horizon, and deep-sea thermometers were not used.

In addition to these a transit and several other instruments belonging to the Case School of Applied Science, and a number of thermometers, aneroids, compasses, etc., belonging to various members of the expedition, were taken with us.

MAGNETIC OBSERVATIONS AT CLEVELAND, OHIO, 1891.

The following observations of the magnetic elements were made at Cleveland on April 6 and 26, May 30 and 31, and June 1, 1891. The station was the pier in the grounds of the City Hospital, which forms the north end of the meridian line laid down by the U. S. Coast and Geodetic Survey. This is the station occupied by the Coast Survey party in 1871 and 1880. It is not far from the hospital building and within 200 yards of the railroad. A passing train did not seem to deflect the needle more than a minute of arc.

The instruments used were Dip Circle No. 12, and the Bache Fund Magnetometer, both belonging to the Coast and Geodetic Survey. A small tent was erected to protect the instruments from the wind and rain.

The magnetic moment of the magnet was determined at the Case School of Applied Science April 6 and on May 26. The needle was oscillated again at the same point on June 9, and the product mH (from the two sets of observations) differed about 1 per cent. This is within the limit of errors of observations. The stirrup supporting the magnet with the two movable cylinders was the same that was used in the observations at Camp Muir, Alaska, in the summer of 1890.

The dip was determined on May 31, and June 1, the values obtained being 72° 34′ and 72° 44′ respectively; mean 72° 39′. This is less than the former values (1880) obtained here by nearly half a degree, but only 11′ less when compared with the observations of 1888 as determined by the U. S. Coast and Geodetic Survey. The secular change is diminishing the dip.

Report of an Expedition to Muir Glacier, Alaska, etc.—Continued.

The meridian line laid down by the Coast and Geodetic Survey was used, and no astronomical observations were made for declination determinations. These were obtained from maximum and minimum elongations.

Declination obtained.

Date.	Mean declination.	Apparent daily range.
1891	° ′	
May 30	2 18·4 W	16
May 31	2 18·3 W	10
June 1	2 19·0 W	9
Mean	2 19 W	12

This declination is about one-third of a degree greater than predicted in Appendix 7, U. S. Coast and Geodetic Survey Report for 1888, p. 264, but only 12′ greater than the revised expression* for the secular variation sent me from the Survey Office, and which includes my observation.

The horizontal intensity was found from observations on April 6 and 26 to be ·1833 and ·1825, average 0·183, which is probably not in error more than 1 or 2 per cent. The total intensity is 0·614 of a dyne.

The nearness of the hospital, the iron railings around the grounds, and the railroad, now make this station an undesirable one for magnetic observations.

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*$D = +0^\circ{\cdot}77 + 2^\circ{\cdot}53 \sin. (1^\circ{\cdot}3\, m - 21^\circ{\cdot}6)$, where m = year of observation—1850.